mitochondrial DNA it emerged, to everyone's surprise, that the genetic code is not always the same. For this work, he was awarded his second Nobel Prize in 1980, jointly with Walter Gilbert and Paul Berg.

Fred Sanger never claimed to be a visionary scientist. He often told colleagues that he was fundamentally an experimentalist more interested in developing quick, easy and reliable methods for sequencing proteins and nucleic acids than in the new knowledge these methods generated. Those of us who knew Fred well and observed him in action in the laboratory never really believed him! Few, if any, biologists since Charles Darwin have had his impact on biology in general, on molecular biology in particular, on biochemistry, on genetics, on medicine, on evolutionary biology, on virology, on immunology, on taxonomy, to name but a few disciplines. His dideoxy method was used to sequence the human genome, although Sanger himself was not directly involved. A significant part of the human genome project was done at the Sanger Centre (later the Wellcome Trust Sanger Institute) named in his honour at Hinxton Hall, Cambridgeshire under Sir John Sulston's direction. Since then many different genomes have been sequenced and annotated, providing unprecedented new knowledge. It is now possible to sequence a human genome or a human cancer in one or two days.

Fred Sanger retired at the age of 66 to spend more time with his family and grandchildren, and to enjoy his hobbies of boating and develop an impressive garden in Cambridgeshire. He received many honours and prizes including an FRS (1954), Foreign Associate of the National Academy of Sciences, USA (1967), CBE (1963), CH (1981), OM (1986), in addition to his two Nobel Prizes. He was a Fellow of King's College, Cambridge and held honorary degrees at Oxford (1970), Cambridge (1983) and many other Universities. Fred was married to Joan Howe, who died in 2012; he is survived by his three children, Robin, Peter and Sally, and two grandchildren.

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Book review

Crossing boundaries: when snake science slithers into art

Rick Shine

Tracks and Shadows: Field Biology as Art
Harry W. Greene
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In 1959, the British novelist C.P. Snow lamented the schism of western society into two disparate cultures — the sciences and the humanities [1]. He argued that both of these cultures provide valuable perspectives, and their failure to communicate with each other hamstrings our attempts to define and solve important problems. C.P. Snow would have loved this book.

I mix with a lot of scientists, and with a few artists as well, but rarely at the same time. Put them together in a room, and it can be a modern Tower of Babel. Intelligent, thoughtful people who need a thesaurus to understand what the other person is saying, let alone why they are saying it. When they find common ground, it's likely to be about topics outside their professional lives. Relationships, children, football teams, cooking and fishing can all build bridges. But it would be a brave biologist indeed who set out to tell his life's story in a non-scientific context, placing deep existential quandaries — prompted by searing experiences like an ex-girlfriend's murder — into the ways that he asks and answers research questions in his professional life as an evolutionary ecologist. And that's what Harry Greene has done in *Tracks and Shadows*.

Scientists are just ordinary people, of course, with all the usual strengths, weaknesses, and obsessions. We all make decisions irrationally, based on a cognitive system that can act like a supercomputer one day, and fall to pieces by virtue of its primate-biology hormonal underpinnings the next. And this matters, for our research as well as for the rest of our lives. Many a scientific collaboration has been built by friendship, or destroyed by jealousy. Most of us try to keep our scientific lives separate from our private lives, but Harry Greene

Figure 1. A diamond python (*Morelia spilota*) out for a morning cruise near Sydney.
Snakes are elegant, mysterious, and secretive — very different from your run-of-the-mill study species — and they attract some equally unusual researchers. In *Tracks and Shadows*, Harry Greene embarks on a personal journey that intertwines events in his own life with the insights he has gathered during a long career spent watching snakes, and trying to understand the world from their perspective. Photograph by Sylvain Dubey.

is an unusual man. His passion for introspection is as great as his love for the snakes that have dominated his research career.

On one level, this book is an autobiography. It tells of an army brat, moving around from one military base to another during his early years, evolving into a mediocre scholar and rock-music enthusiast, then morphing into a creative researcher who has spent his career marching to a different drummer (or perhaps, rattler). Greene's credential are impeccable, by any scientific criterion — he has won a host of awards for his work and his books [2], has generated many novel insights and published them in high-impact journals, and has been a forceful contributor to public debates on conservation issues like rewilding [3]. As a faculty member at Berkeley and then Cornell, his undergraduate courses in vertebrate biology are the stuff of legend.

On another level, the book is a long lyrical love poem to Greene's (and my) organisms of choice — the snakes. And more broadly, to the value of committing to nature; to spending time in the wilds, to observe the minutiae of ecological interactions, and prize the details. Given a choice, Greene would prefer to watch without disrupting — he rhapsodizes over the ecstasy of a day spent sitting in one place in the forest, watching a large viper do almost nothing. But he's not afraid to confront political correctness, and launches into a strong defence of deer hunting. In Greene's credo, you need to engage with nature. And so, if you want to sit back with a steak on the table in front of you, you should be prepared to confront the realities of what needs to happen before you can enjoy that meal.

And on a third level, the book explores people. Especially, field biologists with a fondness for snakes. One central character is Henry S. Fitch, a modest farm boy who conducted a pioneering 50-year study of snakes on what is now the Fitch Natural History Reservation, near Lawrence, Kansas [4]. By the time he died a few years ago, just short of his 100th birthday, Henry Fitch had invented the entire field of snake ecology. He is revered by most of its current practitioners (myself included). Fitch mentored Greene from his early days, and the book returns from time to time to explore that relationship and to try to understand how this gentle man accomplished what he did, and what it meant to him. Henry was too prosaic to use the kind of language that Greene loves — I can't imagine Henry ever saying, as Greene does, "Meanwhile, life winds on like a serpent, seeking shelter, food, and sex, never knowing what lies ahead." But there was clearly a very real connection between the two men, and it was about admiring nature and the value of patient observation, as well as about the adoration of snakes.

The book has a lot of dark moments. An early life as an ambulance driver and medic brought Greene into intimate contact with tragic and messy death, and he doesn't spare us the details. And as he charts his own relationships, and his reflections on the human condition, there are many melancholic memories. But through it all, Greene keeps bounding back, inspired and invigorated by the joy he finds in the natural world. And there are plenty of anecdotes of hanging on to the tails of giant anacondas as they inexorably ooze back into the swamp, and looking up to see a large rattlesnake aiming at you, a few inches away from your face. But this isn't a textbook of snake biology, or a Boy's Own Adventure about the heroic exploits of an alpha male. Greene paints a broad-brush picture of the serpent world, but his focus is on how snakes and people have interacted over our evolutionary history, and how that shared history affects our reactions when a diamondback rattlesnake materializes among the leaf litter at our feet.

Many of Greene's stories will arouse a smile of recognition in anyone who has spent time in the wilderness. The sudden uplift of spirits at the sight of a never-before-seen bird species; the feeling of privilege, mixed with a voyeur's guilt, at stumbling across some unexpected private moment in the lives of your study animals; and the strangely dual impact of a novel research insight, affecting your heart as well as your head. I laughed out loud at the 'bat porn' story, where a group of disheveled biologists, too long in the field, were aroused to erotic fantasies by video footage of a fruit bat tenderly parting the petals of a flower to lap luxuriously at the nectar within.

Every field biologist has their peculiarities, and Greene has more than most. Although he isn't afraid of 'big picture' science (for example, he played a seminal role in placing adaptationist thinking within a concrete phylogenetic framework), he is even more fascinated with detail — with individual organisms, and how they live their lives. He dwells lovingly on one female black-tailed rattlesnake that he radio tracked for over a decade: her movements, her love life, her protective parenting. No matter that his wife was severely envenomated by the same species. Greene argues that we need to pull off a challenging twin view — to appreciate the elegance of these mysterious animals, while accepting that they are natural-born killers. I've never had any difficulty accepting both of those things myself, but I've kept them in separate bits of my brain. Greene isn't prepared to do that — instead, he brings the beauty and danger of venomous snakes into juxtaposition, and works his way through the contradictions that emerge.

A lot of scientists who read this book may feel somewhat staid and prosaic in comparison to the deeply introspective author, who has delved into his emotional reactions to his science in a way that most of us never do. And artists may wonder why we need to understand nature at the scientist's level as well as the poet's. But the book is accessible for both camps, because Greene has a foot in both of them. He has created a rare bridge between the two cultures, and told us what it feels like to be a deeply sensitive research scientist, working in a world where the ecosystems are falling to bits around us. It's a brave book, and somewhere out there in the darkness, I can hear C.P. Snow applauding.

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